

CENTER FOR X-RAY OPTICS  
ADVANCED LIGHT SOURCE

# X-RAY DATA BOOKLET

Albert C. Thompson, David T. Attwood, Eric M.  
Gullikson, Malcolm R. Howells, Jeffrey B. Kortright,  
Arthur L. Robinson, and James H. Underwood  
—*Lawrence Berkeley National Laboratory*

Kwang-Je Kim  
—*Argonne National Laboratory*

Janos Kirz  
—*State University of New York at Stony Brook*

Ingolf Lindau, Piero Pianetta, and Herman Winick  
—*Stanford Synchrotron Radiation Laboratory*

Gwyn P. Williams  
—*Brookhaven National Laboratory*

James H. Scofield  
—*Lawrence Livermore National Laboratory*

*Compiled and edited by*

Albert C. Thompson and Douglas Vaughan  
—*Lawrence Berkeley National Laboratory*

Lawrence Berkeley National Laboratory  
University of California  
Berkeley, California 94720

Second edition, January 2001

This work was supported in part by the U.S. Department of Energy  
under Contract No. DE-AC03-76SF00098

---

# CONTENTS

---

<b>1. X-Ray Properties of the Elements</b>	<b>1-1</b>
1.1 Electron Binding Energies <i>Gwyn P. Williams</i>	1-1
1.2 X-Ray Emission Energies <i>Jeffrey B. Kortright and Albert C. Thompson</i>	1-8
1.3 Fluorescence Yields For <i>K</i> and <i>L</i> Shells <i>Jeffrey B. Kortright</i>	1-28
1.4 Principal Auger Electron Energies	1-30
1.5 Subshell Photoionization Cross Sections <i>Ingolf Lindau</i>	1-32
1.6 Mass Absorption Coefficients <i>Eric M. Gullikson</i>	1-38
1.7 Atomic Scattering Factors <i>Eric M. Gullikson</i>	1-44
1.8 Energy Levels of Few-Electron Ionic Species <i>James H. Scofield</i>	1-53
<b>2. Synchrotron Radiation</b>	<b>2-1</b>
2.1 Characteristics of Synchrotron Radiation <i>Kwang-Je Kim</i>	2-1
2.2 History of Synchrotron Radiation <i>Arthur L. Robinson</i>	2-17
2.3 Operating and Planned Facilities <i>Herman Winick</i>	2-24

<b>3. Scattering Processes</b>	<b>3-1</b>
3.1 Scattering of X-Rays from Electrons and Atoms <i>Janos Kirz</i>	3-1
3.2 Low-Energy Electron Ranges In Matter <i>Piero Pianetta</i>	3-5
<b>4. Optics and Detectors</b>	<b>4-1</b>
4.1 Multilayers and Crystals <i>James H. Underwood</i>	4-1
4.2 Specular Reflectivities for Grazing-Incidence Mirrors <i>Eric M. Gullikson</i>	4-14
4.3 Gratings and Monochromators <i>Malcolm R. Howells</i>	4-17
4.4 Zone Plates <i>Janos Kirz and David Attwood</i>	4-28
4.5 X-Ray Detectors <i>Albert C. Thompson</i>	4-33
<b>5. Miscellaneous</b>	<b>5-1</b>
5.1 Physical Constants	5-1
5.2 Physical Properties of the Elements	5-4
5.3 Electromagnetic Relations	5-11
5.4 Radioactivity and Radiation Protection	5-14
5.5 Useful Equations	5-17

---

## PREFACE

---

For the first time since its original publication in 1985, the *X-Ray Data Booklet* has undergone a significant revision. Tabulated values and graphical plots have been revised and updated, and the content has been modified to reflect the changing needs of the x-ray community. Further, the *Booklet* is now posted on the web at <http://xdb.lbl.gov>, together with additional detail and further references for many of the sections.

As before, the compilers are grateful to a host of contributors who furnished new material or reviewed and revised their original sections. Also, as in the original edition, many sections draw heavily on work published elsewhere, as indicated in the text and figure captions. Thanks also to Linda Geniesse, Connie Silva, and Jean Wolslegel of the LBNL Technical and Electronic Information Department, whose skills were invaluable and their patience apparently unlimited. Finally, we express continuing thanks to David Attwood for his support of this project, as well as his contributions to the *Booklet*, and to Janos Kirz, who conceived the *Booklet* as a service to the community and who remains an active contributor to the second edition.

As the compilers, we take full responsibility for any errors in this new edition, and we invite readers to bring them to our attention at the Center for X-Ray Optics, 2-400, Lawrence Berkeley National Laboratory, Berkeley, California 94720, or by e-mail at [xdb@grace.lbl.gov](mailto:xdb@grace.lbl.gov). Corrections will be posted on the web and incorporated in subsequent printings.

Albert C. Thompson  
Douglas Vaughan  
*31 January 2001*